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О ГОРОХЕ И ГОРОХОВОЙ ЗЕРНОВКЕ.

I. I. KORAB.

THE PEA AND THE PEA WEEVIL.

БІЛА-ЦЕРКВА 1927.

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"Among the plants which for economic reasons it would be desirable to introduce in crop rotation in the southern and southwestern parts of the country and even in the "black earth" belt, a high place must be assigned to the pea.

Unfortunately the literature on the cultivation of this valuable plant is very scanty and furthermore is of a highly theoretical nature.

P. R. Slegkin "Husbandry", 1913.

Introduction

The cultivation of the legumes has been of special importance to present day agriculture ever since it became known that these plants, in addition to their own valuable products, are distinguished for their nitrogen-gathering properties. It is now generally understood that the legumes, and especially peas, act to enrich the soil, and as a result these plants deserve first place among plants to be chosen for field cultivation.

But in actual fact the reverse is the case, and we are finding a lamentable decrease in the cultivation of some of the legumes, always as a sequal to a period of increase.

Among the grain legumes the pea is of special importance, but its cultivation has been subject to the harmful action of a small beetle, Bruchus pisorum L., the so-called pea weevil, which has completely over-run it.

The pea weevil, that most dangerous and persistent foe of the pea, makes the cultivation of this crop of little profit; for after attempts have been made to plant large areas tó peas the weevil multiplies so rapidly that the farmers are at length obliged to give up all idea of extending this crop in that locality.

Perhaps no other one of man's cultivated field crop is

so completely at the mercy of its pest as is the pea at the mercy of Bruchus pisorum L.

Whole provinces which have been raising peas on a large scale have been obliged to restrict their plantings as a result of the obvious unprofitableness of further cultivation. (P. R. Slezkin, General survey of the cultivation of leguminous plants, Yearbook of Department of Agriculture, 1914).

As the product becomes less desirable from the consumers' standpoint, the demand for peas that have been infested by this beetle drops rapidly; and the planter is forced to replace his pea plantings by some crop more acceptable to the consumer and the dealer.

The pea weevil, in contrast to most farm pests, is not subject to sharp fluctuation in numbers. The tide that overwhelms the farmers is more or less constant over a series of years, and even shows some tendency to increase, depending on the intensiveness with which the pea is being cultivated in the locality in question, since under present conditions of field cultivation an expansion of pea plantings brings with it an increase in the numbers of the weevil.

The pea plant is one which enriches the soil with nitrogen and makes an excellent forerunner for sugar beets and winter wheat, and it is therefore very useful for rotation of crops in beet culture; here it plays a quite different part from its role in the regions where it is most widely distributed.

The agricultural importance of the pea weevil extends north to about 52° NL, the boundary of Kura, Voronezh and Saratov provinces. Thus the whole territory of Ukraine, except for a few places, is so over-run by the pea weevil that here the pest sets the limits, at its own pleasure, for the more or less successful development of the field cultivation of the pea.

Even in the provinces of Ryazan, Tula and Penzen they have ceased to plant peas because the crops have suffered so severely (ibid).

Few of the known pests of farm plants have proved to be so susceptible to transportation over long distances as have insects of the weevil family, the Bruchidae. Living the greater

part of their lives inside the seed, they easily survive any journey; your weevil is a true cosmopolitan. It can easily be found even in the fields around Leningrad, and sometimes still farther north. Even there it sometimes attacks peas, but to a very limited extent and not every year.

The pea weevil found in the north comes there with the seed. Every year large numbers of the weevil reach northern markets from the south. Making its escape in the spring, the weevil sometimes finds its host plant even there in nearby fields, but it does not flourish in the climate of the north. It is certain that if the supply was not renewed every year the weevil would soon be a wholly extinct species of insect in those latitudes.

The damage done by the pea weevil is not limited to loss of weight in the infested grain, and decline in viability and in commercial value. There is the added difficulty that when the infested pea is used as food it is dangerous to health. The injurious properties of such peas are caused not only by the presence of the pest itself, but in even greater degree by the presence in the partly eaten seed of the excrements of the larva, which has been developing in it. Porchinski quotes several authors (Curtis) who testify that when peas infested by the weevil are used as human food the health of those who eat is impaired. The injury is caused by the fact that in the larval excrements which are there, and also in the body of the insect, is a cantharidinous substance which causes severe inflammation of the intestines, kidney and urinary tract.

The damage done to agriculture by this pest is figured at a yearly total running into several millions of rubles in direct loss. This figure does not take into account the losses sustained in replacing this very valuable crop with a plant of lower value.

In countries where the grain legumes are cultivated on a large scale, for example, the United States and Canada, the damage done by the pea weevil reaches a yearly total of several million dollars in direct losses.

In a single one of the southern provinces of canada the losses to agriculture caused by the pea weevil are reconed at a million dollars.

The market value of the product is everywhere affected by the presence of the beetle in the seed, and market prices depend upon the extent of infestation. If the ordinary price of peas has been two rubles a pood, peas infested by the weevil will sell at half that (Slezkin).

Table I. Viability under natural conditions of peas of different sizes, infested and not infested by the pea weevil.

Name of variety	Size of seed	percent of seeds germinating	
		not infested by the weevil	infested by the weevil
Victoria Heine	large	95	27
Folger Heine	medium	92	13
6023 Moscow station	small	86	2 *

*plants soon died.

Thus the actual decrease in viability of the seeds attacked by the pea weevil may be regarded as equal to the (?) percent of seeds infested. This is more the case with the fine-seeded peas. Of the peas with large seeds about 25% of the variety Victoria sprouted and about 10% of Folger.

General characteristics of the pea weevil.

The pea weevil, Bruchus (Laria) pisorum L., belongs to the family Bruchidae, genus Bruchus (in view of the existing controversy over Piot's nomenclature -- Lariidae, Laria -- I am here following Reiter's nomenclature--Bruchidae, Bruchus). All the member of this family are herbivorous beetles. In most cases their larvae live in the seeds of various leguminous plants. Genus Bruchus includes several hundred species (more than 800). All the Bruchidae except a few tropical species of weevil grow in the seeds of a single family of plants, the Leguminosae, and are distributed all over the world. Of the species which have an economic significance a great many infest the grain legumes. This is probably connected with the fact that these plants have comparatively large seeds which provide a good place for the development of the larva and of the insect itself. The pea weevil is confined to the seeds of the pea. In most cases, moreover, it is satisfied with a single seed for its development.

Рис. 1. Гороховая зерновка *Bruchus pisorum L.* Ориг. рис. С. А. Смирнова.

Figure 1. Pea Weevil Bruchus pisorum L. Original drawing by Smirnov

It does not attack the seeds of other legumes. The weevils found in seeds of the bean (B. rufimanus Boheman), the lentil (B. lentis Boheman), the kidney bean(B. obtectus Say) the HYT (Cicerarietimun) (B. quadrimaculatus Fabricius, B. chinensis Lin. Spermophagus pectoralis Say), and other cultivated legumes, also those in some of the wild legumes, belong to other species and have nothing in common with the pea weevil. The pea weevil's generation is one year.

The history of these pests, according to Mochulski (Pea weevils, Bruchus Linne, which attack legumes. Proc. Lib. Econ. Soc. 1854, 1) and Keppen (Injurious insects, Vol. II, 1883), is as follows: The pea weevil is a native of North America. It was first discovered in Pennsylvania. In 1738 the weevil was found farther north, around New York. The Swedish traveler Kalm seems to have been the first to take it to Europe, in 1758. Here it found conditions favorable to its diffusion. By 1810 peas in England were so badly infested that they could not be used for army and navy supplies. The pea weevil is mentioned in France as early as 1780.

In Russia, according to these authors, the weevil first appeared in the south. In 1851 and 1852 it did much damage to peas in two districts, Bakhmut and Alexandria, in Ekaterinoslav province. After that the weevil appeared in Khersonese in such numbers that in eight bushels of peas there was not even a peck of sound seeds. In 1872, according to Sempolovski (Agricultural Gazette, 1892, 27, St. Petersburgh) it caused a great deal of commotion in Warsaw, where it was regarded as extremely poisonous.

Short description of the insect.

Widely oval beetle, flattened, black with dense rusty gray down. Whitish spots on each wing-cover, forming stripes. Wing-covers shortened so that they do not cover last two abdominal segments. Last tergite (pigidium) with two large oval black spots. These spots here form a characteristic cross-shaped white spot. Pronotum with large lateral emargination. Antennae straight, eleven-segmented, slightly thickened at apex. First three segments of antennae and of tibiae and tarsi of front legs, and often half of tibiae and tarsi of middle legs reddish. Hind femora with one tooth on inner side. Adult measures four or five millimeters.

Larva in first stage (before moulting) is reddish, and has legs with three segments. These legs disappear with the first

moulting. Anterior portion of back of larva has two peculiar chitinous appendages which are clearly seen from the side. These too disappear after the first moulting. Body is covered with sparse but long bristles.

Full-grown larva is five or six millimeters long, cream-colored, sometimes with yellowish tint. Small head is the same color, deeply withdrawn into much thickened thoracic division. Jaws brown. Nipple-shaped warts in place of legs. Full-grown larga is bare, with only a short down on under side of thorax.

Metamorphosis of the weevil.

Eggs are laid by the female weevil on unripe fruits of leguminous plants, and in the course of six to ten days the larva with legs comes out. The freshly emerged larva bores into the tissue of the pod, enters its cavity, and there eats its way into the seeds, which are still soft. After several days it moults and then becomes quite unrecognizable. As a result of the moulting the weevil larva takes the form of a worm without legs and with a small head, and its light orange becomes a cream color. A few weeks after this stage the larva is transformed into a free pupa, and then into a winged beetle. Depending on temperature conditions, the adult insect may come out of its cavern promptly and leave the seed, or may remain there for a more or less prolonged period. Thus the individual weevil undergoes not three stages of development, larva, pupa and adult, but four, as follows: 1) larva of the first type, 2) larva of the second type, 3) pupa and 4) adult. Thus we have here a special kind of metamorphosis, the so-called hypermetamorphosis. The weevil larva undergoes two stages of development, in that the newborn larva has three pairs of legs, also a special tooth-like chitinous appendage on the anterior part of the back, while the larva of the second stage has no legs; they are replaced by nipple-shaped appendages which look somewhat like undeveloped legs. Furthermore, this second stage of the larva is usually hairless, while the larva of the first stage is covered with sparse long hairs. The hypermetamorphosis of the weevil is distinguished from the hypermetamorphosis of some other insects by the smaller number of successive stages of development. There are not two pupa phases here, as there are in beetles of the Meloidae genera, but only one, as in the normal type of complete metamorphosis. A variation of this complex metamorphosis is to be seen in a number of other families of insects, as for example in the bot-flies of the family Oestridae.

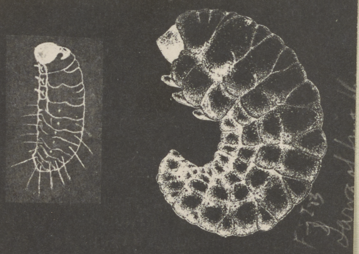


Рис. 2 и 3. Личинка первой фазы и взрослая
личинка гороховой зерновки.
Оригин. рис. автора.

Figures 2 and 3. Larva of the First Phase
and full Grown Larva of the Pea
Weevil. Drawings by author.

Biology of the pea weevil

The time when the peas begin to blossom always determines the time when the weevil appears on the pea fields; before that, as a rule, the beetle is usually absent. It seems to be attracted to the fields by the fragrance of the blossoms, and flies to its host plant from a distance. The earliest arrivals of the insect in the pea fields that we have observed were in 1923 1/VI, in 1924 29/V, in 1925 30/V, in 1926 25/V, and in 1927 30/V. Usually the beetles fly to the peas on the day following the blossoming of the earliest varieties. At first the weevil sits on the pea very discreetly, sometimes eating large holes in the blossoms. Usually these attacks on the corolla of the pea blossom do not do any lasting injury. While it is eating the delicate tissue of the blossoms the weevil does not touch the ovary, stigma or stamens. But later, when we artifically brought about a dense crowding of beetles in our isolation plantings, they did so much harm to the blossoms and also to all the delicate growing part of the plant that they not only prevented any further blooming but also injured the whole plant. When it comes out of the pea seed, where it has been resting in the beetle stage for eight or nine months (September to May) the weevil needs supplementary food.

Keeping out of sight during its first time on the field, the weevil patiently awaits the appearance of the pods, in order to perform its principal task of caring for posterity. Later we observe that each day there are more and more weevils on the peas. In the hot hours of the day the beetles fly briskly around and mate. On dull or rainy days, and also in the morning and evening, the beetles remain motionless in the depths of the corolla of the pea, where they can always be easily found.

Laying the eggs

The egg-laying of the pea weevil has always been of interest to us for practical reasons, and hence it was made the object of our observations during the course of several generations.

The pea weevil begins to lay eggs on the peas in the first days of June. In practice this date corresponds with the date when the young pods are formed, which in the climate of Belaya-Cerkov is usually not before the end of the first ten days of June. From this time on the number of eggs laid each day on the young pea pods increases gradually, reaching its maximum in the second or third ten days of June, which is properly the time of heaviest infestation by the pea weevil.

This period of most intensive egg-laying lasts only about ten days, usually from June 15-18 to June 25-28, and withing certain narrow limits it may vary with weather conditions.

The earliest laying of weevil eggs on the newly formed pea pods that we observed in nature occurred on May 29. That the pea weevil cannot lay eggs earlier than this is indicated by results of a special experiment which we performed; in a hot-bed we artifically forced a pea (Early Jaun) so that it blossomed at the end of April and began to fruit early in May.

Results of this experiment indicate that in our climate the pea weevil cannot lay eggs earlier than the month of June.

The egg-laying period of the individual is not long, and can be wholly included within a period of fifteen days. In Nature the egg-laying period is composed of the periods of huge numbers of the insects, and hence the length of the period in which the pea weevil is able to lay eggs is often given as greater than observation of individuals corroborates.

In nature the weevil's last eggs usually come in July, and by that time there are only a few.

The prolonging of the period of egg-laying depends on the one hand upon meteorological conditions, and on the other upon the prolonging of the period during which the weevils fly to the pea fields.

An overwhelming number of weevils normally comes in connection with ~~the~~ an open early spring, for the weevil falls to the ground with the seeds. For most of the weevils the rhythm of life comes to an end at the moment when the weevil's chief duty to posterity has been performed. Usually by the beginning of July this duty to posterity has been fulfilled, its life is cut short, and in nature it soon disappears.

Meanwhile it is often possible to find the insects on the fields even beyond the limits of the stated time, but in very small numbers. They may even lay eggs there, to mystify the observer not prepared to find beetles at so late a date.

But at the end of June and even in July, if you will investigate last year's peas left in the warehouse and the condition of the weevils inside, you will find that there are still a great

many who are quite alive, and mary active if they finally succeed in escaping from their cradles. As I shall show later beetles taken from there for study proved to be able to lay eggs in July almost as successfully as the beetles that had flown in. Although they form only a small proportion of the beetles that were here earlier, nevertheless this reserve supply is quite sufficient to leave its mark when it falls on the field.

Furthermore, these casual specimens of weevil are the fundamental source of the disagreement in the estimate of the liability to infestation of the late-ripening varieties of peas. In cases where the testing of varieties is done om small plots, it serves as a decoy for such of the weevils as are still wandering around. Consequently these varieties are sometimes much infested.

Table 2. Egg-laying of the pea weevil in field isolation plantings which were set out late.

No. of planting	Date when beetles were put on planting	Date when beetles were taken off planting	Date of egg laying observed	No. of eggs laid
1	7/12	7/27	---	---
2	"	"	7/15	33
3	"	"	7/15	177
4	"	"	---	---
5	"	"	7/15	32

The female pea weevil lays her eggs on the surface of young green pea pods. She shows a preference for pods of middle size which have completed their growth in length and width. Apparently this saves the eggs from being displaced in the course of the growth of the pod tissue.

Table 3. Egg-laying of Bruchus pisi by individual pairs in field isolation plantings

No.	Date of putting beetles on plantings	Date when egg-laying was first observed	Date of taking off plantings	Number of eggs laid
1	6/3	6/6	7/6	158
2	"	6/7	6/29	69
3	"	6/4	7/6	138
4	"	6/6	6/26	175
5	"	"	"	95
6	"	"	"	222
7	6/4	-	7/6	-
8	"	6/17	"	82
9	"	6/6	"	61
10	"	6/8	"	70
11	"	6/6	"	124
12	"	6/5	"	19
13	"	6/6	6/30	142
14	"	-	7/6	-
15	6/9	6/16	6/26	75
16	6/15	"	"	76
17	"	6/17	"	96
18	6/17	-	6/29	146

We made observations on the number of eggs laid by the weevil directly on the fields under natural conditions, isolating the plants by the use of muslin wrappings. Results of these observations are given in the following table.

Table 4. Egg-laying of __Bruchus pisi__ by individual pairs in field isolation plantings.

No.	Date of isolating	Egg-laying day by day																				Length of egg laying period	Total of eggs laid
		6/6	6/7	6/8	6/9	6/10	6/11	6/12	6/13	6/14	6/15	6/16	6/17	6/18	6/19	6/20	6/21	6/22	6/23	6/24	6/25		
1	6/3											10	28	5	15		6	4	7	1		9	76
2	"	20	1	26	8	18	21	21	22	22	2	14										11	175
3	"	2								31	10	6	3	7		16	14		4	1	1	11	95
4	6/9	34			16	33	1	17	18	18	35	12	4	13	9	2						15	222
5	6/15												38	19	29	7	2	1				6	96
6	6/15											2	9		47	11	4	2				7	75

These observations, which were made with all possible care, show that the reproductive powers of the pea weevil are far from small. One female may lay 222 eggs in the course of her life. According to these figures the weevil lays an average of about 126 eggs.

Under normal conditions, i.e., when the weevil has aan unlimited number of plants at its disposal, the number of eggs laid on a single pea pod is usually about three.

The eggs are amber yellow in color, elongate-elliptical in shape, and measure about 0.6 mm.; the female sticks them to the surface of the pea with a gluey fluid secreted for this purpose. When it dries, this glue forms charscterictic spots and streaks.

Table 5. Egg-laying of the pea weevil in captivity. The pairs of beetles were kept in glass jars in the laboratory window.

No.	Date of first egg laying	Number of eggs laid Month of June									Total number of eggs
1	6/16	19	20	21	22	23	24	25	26	27	9
2	"	2			26	18	9	5	6	10	76
3	"				20	32					52
4	"							23	6	7	36
5	"				17	15		23	22	6	83
6	"				15	17		8	19		59
7	"					12		33	32		77
8	"					37					37
9	"				19	20	14	14	19	5	91

Eggs laid by pea weevil on pea pods

Рис. 4. Кладка яиц гороховой зерновкой на бобах гороха.

Figure 4. Eggs Laid by the Pea Weevil
On Pea Pods

The female first goes over the place it has selected with movements of the end of the abdomen, or rather of the ovipositor, and this rubbing of the part chosen by the insect is accompanied by secretion of a certain amount of glue. In this spot of glue the weevil lays its wggs, and then withdraws to a distance of only a few millimeters to repeat the operation. These amber yellow eggs, rather large in proportion to the size of the insect, are easily seen against the green surface of the young pods. They can always be easily noted on the peas in the month of June.

The number of eggs on a single pod is not fixed. In most cases there are several times as many as the number of larvae that can live on the supply of food in the pods. Often, especially on small plots, we found pods on which we counted 35 eggs, but 17 was the average number of eggs in the period of most intensive laying. Such wastefulness on the part of the weevil is in direct contradiction to the maternal instinct; an overwhelming majority of the larvae that come out of these eggs are doomed to destruction in the struggle for existence.

Larvae of this insect do not allow even two to live at the same time on one pea. Most of them die in the early stages of their development; those that prove to be superfluous die very mysteriously in the presence of an abundance of food and under conditions which would seem to be entirely favorable to their welfare. Although the pea furnishes a rich storehouse, it is evidently not enough for two inhabitants. Only one of the weevil larvae that have entered the pea continues to grow and develop normally. The others, probably guided by some special instinct, cease to exist, and die in infancy in their tiny cradles.

The larvae die long before the time when they might decide their right to existence by an open struggle, although such a happening is not unknown among the pea weevils. Often in breaking open a pea in which two larvae have been developing side by side one can see a chamber which is at first glance empty, but closer examination shows to contain the withered body of the second larva, the unsuccessful combatant in the struggle for life's comforts. When they come into direct contact the larvae decide their fate by the use of their jaws, and often both perish in the struggle. More frequently, however, the victor in this combat lives the rest of his life happily with no further interference. Gases of two weevils living in ome pea are extremely rare. Thus before the imago stage only one specimen of weevil at a time can live in each infested pea.

Eggs of the pea weevil are often found even on very young fruits of the pea, as early as the second day after the falling off of the corolla. In view of the fact that these do not furnish suitable food for the weevil, we might be doubtful of the further welfare of the larva, except that observations on the growth of the pea pods have convinced us that there is no danger to the larva from this direction. Daily measurements of the length and width of pods which we made throughout their period of growth indicated that pea pods complete their growth in length and width within seven days of the time when the corolla falls off. The embryonic development of the larva usually takes place during this period, and it emerges on the sixth or seventh day, thus at the moment of its emerging it is fully assured of the proper food and of all the conditions needed for its further existance.

The time required for the development of the larva in the egg varies from six to ten days. Before it breaks through the shell the brown head of the larva can be seen. Soon after this the larva comes out of the egg and eats through the outer envelope into the sáft juicy part of the pea. We were never able to observe the piercing of the envelope of the pod by the newly emerged larva before it entered the cavity of the pod, The larva takes a zigzag course in the tissue of the envelope of the pod only in those cases in which this process is observed in the laboratory, and when the green wrappings of the pea have faded a little. Then indeed its bright and winding course, visible from the outside, sometimes extends five millimeters. Under field conditions the larva in most cases took a verticle direction at once, and not only bored quickly through the fleshy green envelope of the pod but coped successfully with the hard tough parchment layer. The opening made by the larva can first be seen inside the pod as a bright diffused spot of glistening tissue. Under a magnifying glass the very small opening made by the larva can easily be seen. Thus the place where the weevil larva enters the cavity of the pod is determined in most cases by the place where the egg was deposited on the surface.

In order to demonstrate the length of time spent by the weevil in each of its stages during its development in the pea, we set aside in the field the required number of pods not yet infested; the next day all these pods were examined again and those of them which already showed weevil eggs on their coverings were isolated. After the larvae had come out of the eggs, we tore apart one pod each day and determined how far the insect's development had advanced.

Table 6 - Development of weevil *Bruchus pisi* in pea seeds.

No. in order	Age of insect in days	Size of insect in mm. Length	Width	Stage of insect	Remarks
1	1	0.5	0.2	Larva of 1st stage	
2	2-3	0.7	0.3	" "	Moment of 1st molting
3	8-9	1.3	1.0	2nd "	2nd "
4	11-12	2.1	1.4	3rd "	3rd "
5	15-16	2.45	1.45	" "	" "
6	18-19	2,3	1.45	4th "	4th "
7	21-22	3.0	1.8	" "	
8	24-25	3.15	1.8	" "	
9	27-29	4.4	2.5	" "	
10	30-31	4.0	2.5	" "	
11	33-34	4.5	2.5	" "	
12	36-37	4.6	7.7	" "	
13	39-40	4.6	2.9	Pronymph	5th molting
14	41-42	5.2	2.4	Pupa	
15	52-53	4.7	2.5	"	
16	53-54	5.3	2.45	"	
17	56-57	5.2	2.5	"	
18	59-60	4.8	2.4	"	
19	61-62	4.7	2.4	"	
20	64-65	4.8	2.4	pupa with small dark head	
21	67-68	5.1	2.4	young beetle	

Figure 5. Weevil Eggs on Pea Pods
Drawing by the Author

Behavior of weevil under natural conditions.

One of the interesting chapters in the study of the biology of the pea weevil deals with its ability to accomplish quite long flights in case of need. In the spring the beetles usually fly away from their winter dwelling and scatter widely. This may perhaps explain why peas do not escape infestation even when there seem no other way for the pest to have reached a given field, and when there are no pea fields nearby. Very often, in spite of the fact that planting was dome with peas not attacked by the pest, by the time the peas blossom there are so many beetles that one cannot help thinking of the possibility of their traveling to very distant sections of the field.

We consider this matter of the insect's ability to make long flights one of the interesting questions in its biology. We wished to solve the riddle presented by the infestation of peas by the weevil in cases where planting had been done with seed not attacked by the pest, and at the same time there were no other plantings within a distance of several versts. In other words, when all precautions for preventing infestation had been carefully carried out.

In our latitudes the beetle probably finds it difficult to survive the winter in the open. It does not always leave its cradle in the fall. The metamorphosis of the pupa into the adult beetle inside the seed takes place no earlier than the middle of August. Moreover, the beetles do not usually fly well in the fall, and in general do not show the mobility displayed by individuals which come out of the pea in the spring. It sometimes happens that in the fall, under the influence of warmth, numbers of the beetles come out of the peas stored in warehouses, make their way toward the light, and congregate on the granary windows. Many then leave the storehouse and make for the open. But in so doing they suffer great and continuous loss of energy, and as a result they soon die, covering the window sills with their corpses. Those that survive until spring are the ones that retire into cracks and there wait quitely, conserving their strength for a season better fitted for active life, i. e. for spring.

In heated buildings the beetles die of exhaustion within two weeks after they have come out of the peas.

In the period of its active life, this insect is generally very difficult to find. Even in spring, before the peas blossom,

when the beetles are relatively much more numerous in nature, they are seldom to be seen when special trips are made. And it is even more difficult to find them in the open in the fall . Nevertheless, it seems impossible to deny that the weevil may live over the winter under natural conditions.

The open conditions of nature give very little possiblity for surviving the hazards of winter and its accompanying seasons. We have never succeeded in finding any weevils living over the winter in the open in any cracks on tree bark or any of the other places mentioned on the literature. Apparently the climatic conditions of our latitude do not permit the beetles to find any shelter in the open, but in the absence of more positive proof we shall leave this question unanswered until next spring.

The main supply of these pests is unconsciously but very carefully preserved by the farmers themselves in their storehouses. Then in the spring, when it is time for the insects to wake up and set forth, the farmers again give them every opportunity. With the coming of the warm days of spring, great numbers of weevils leave the granaries, unnoticed, and fly away in all directions. Another army of pea weevils the farmer's own hand carefully plants in the field, together with the pea seeds. Then the weevil, placed in the ground at the depth at which the seed is planted, comes easily to the surface with the beginning of the warm days; but neither the first group nor the second is attracted at this season to the first green of the pea fields.

Of the weevils placed in the ground with the seed at sowing time, almost all come to the surface. The only ones to die are the individuals which have somehow been weakened; these as a rule stay in the seed instead of flying out. The number of weevils that succeed in getting through the thickness of the layer of earth covering is indicated in figures obtained by an experiment which we arranged for this special purpose.

Рис. 6. Различная величина зерен гороха поврежденного *Bruchus pisi L.*

Figure 6. Varying Sizes of Pea Seeds
Attacked by *Bruchus pisorum* L.

Table 7. Results of experiment on the pea weevil's ability to come to the surface of the soil when the seeds are placed at varying depths.

No. in order	Depth of seeds in cm.	Number of seeds planted	Observations on beetles coming to durface of soil — April 4/18	4/20	4/26	4/28	4/29	4/30	May 5/1	5/3	5/4	5/9	5/13	5/17	5/20	5/24	5/30	June 6/4	6/8	6/10	Total number that came out.	Results of analysis of soil 21/VI — Beetles found — Dead	Alive
		Planted April 8.																					
1	1	40	5	5	12		2	1	1	3											29	10	1
2	3	"			3	1		4	1	1	2	2		2							16	21	3
3	5	"				1	1	1	1	1	1				1						7	30	3
4	7	"										1	1		2	2					6	25	9
5	9	"												1		2		2			5	24	11
6	11	"															3	1			4	25	11
7	13	"															1	2			3	33	4
8	15	"																1			1	35	4
		Planted April 13																					
9	1	40	13	3	2	2	1	1	1			2	1				3	1	1		31	9	–
10	3	"			1	2	1	2	1	6	1	1		1			1				17	23	2
11	5	"				4		1	1					1				1	2		10	30	–
12	7	"				3		2	1		1		2			2					11	28	–
13	9	"					2		3		1		3		1						10	30	1
14	11	"									1			2	3	2	2				10	28	2
15	13	"											1		2	1	1				5	35	–
16	15	"														3		2	2	1	8	32	–

The rate at which the beetles come out of the pea seeds in the spring varies, of course, with the conditions under which the grain is kept. A comparative table of this biological feature of the weevil has been compiled from the figures which our observations gave us, and is reproduced below. The observations of the flight of the weevil from the pea seed were made at three places at once --- in rooms on the first floor of a stone warehouse, in the garret of a warehouse roofed with iron, which was therefore very hot when the sun was shining, and lastly in the insectary.

Table 8.

Table 8.

Place of observation.	No. of seeds with beetles.	Mar. 20–25	Mar. 26–31	April 1–5	April 6–10	April 11–15	April 16–20	April 21–25	April 26–30	May 1–5	May 6–10	May 11–15	May 16–20	May 21–25	May 26–31	June 1–5	June 6–10	June 11–15	June 16–20	June 21–25	June 26–30	July 1–5	July 6–10	July 11–15	July 16–20	July 21–25	Total of beetles to come out: No.	Total of beetles to come out: %	Total remaining in seed: Dead	Total remaining in seed: Alive
Garret	400	1	1	2		27	6	2	26	19	10	5	12	18	16	2	3	4									154	38.5	229	17
First floor	"					3	1	1	6	34	4	6	8	19	12	70	30	8	8	1	2	1				1	215	53.7	147	38
Insectary	"	1			4	14	3	1	25	33	5	3	6	55	43	10	11				2	2	2				220	55.0	176	[illegible]

Beetles observed to come out of the seeds, in five-day intervals

This table shows that it takes quite a while for the weevils to crawl out of the pea seeds. In the open air and in the stone warehouse the beetles were still flying in July. The greatest prolongation of this period of crawling out was in the stone warehouse. The death within the pea seed of a large proportion of the weevils was observed to depend upon the conditions under which they were kept. In the attic under the iron roof, where there were great fluctations of temperature and the atmpsphere was deficient in moistute, up to 50% of the beetles died in the seeds.

In the early part of the pea's development and even up to the moment when it blossoms, there are no beetles on the pea fields. At this time the insects are widely scattered over the surrounding territory, and are to be found on the pea fields only rarely. Where the weevil wanders at this time, what plants provide it with shelter and food, we do not definitely know.

It has been said that in the early spring, before the peas blossom, the weevil lives in the blossoms of the willow, but in our country the willows blossom so early that with our weather conditions the weevil cannot be there. We must assume that the beetles do not confine themselves to any two or three species of plants, but visit at random a great number of plants blooming at this season.

At the end of May the early varieties of peas begin to blossom, and from that time on the pests begin to come in from all around to the fields planted to peas. At first single individual weevils take up their abode in the newly opened corollas of the pea pods, there they usually remain motionless for a while. If one looks cautiously into the middle of the pea blossom in the morning or evening, when the beetles are generally less given to moving about, the weevil can be seen hidden in the depths of the corolla. As I have said before, the beetles often eat great holes in the different parts of the corolla, but they never touch its more important organs, either the stamens or the young ovaries. We have never been able to find that any harm was done by this partial eating of the corolla of the pea blossom.

From the moment when the pea pods are formed the weevils gather in the fields, guided, apparently, by the characteristic scent of the blossoming plants. For the present we may assume that some fragrance from the pea blossoms which is not perceptible to us attracts the pea weevil from the distant places where it happens to be. We need to give much attention to the special instinct

of this insect which keeps it in such close communication with the plant that is its food. It is instinct, nothing else, this highly developed and powerful stimulus which guided the weevil in its search for the plant that is to nourish the future larva.

In 1926, in order to determine the weevil's ability to make relatively long flights in its search for the host plant, we conducted the following experiment.

Beginning in May we released marked weevils every four or five days from houses in the village of Alexandria, a suburb of Belaya-Cerkov. In order to mitigate the difficulties involved in searching for the particular beetles we had released, among the vast numbers of beetles not marked which would be found in every pea field, the experiment was carried out on a large scale. In the course of two weeks we released about 56,800 specimens of weevil (1000 beetles of Bruchus pisi weight 9.4 grams). Even though we used such large numbers for the experiment, it was difficult to locate the beetles, because they were so widely dispersed within a radius of several versts (verst - two thirds of a mile).

The insects were given a lasting color easily seen by covering them with a bronze powder (gold leaf). The flecks of bronze remain long unchanged on the insect's body, and as a result the beetles can be easily distinguished among a mass of uncolored insects even after some time. To make the bronze stick better and stay on longer, the insect was sprayed with a suspension of egg-white in water applied by a rubber hand atomizer, and the powder dusted on after this. After it dries this forms an adhesive layer around the insect's body, and under natural conditions is not washed off for a long time.

The first of the pea weevils on the pea blossoms of 1926 were discovered May 28, and we began to find the marked beetles immediately after that, but only rarely. We took several of them at a distance of three and a half versts from the place where they were released. Here it should be added that under the conditions we have just described the beetles were greatly handicapped in their movements. In its flight the weevil had to cover a verst and a half of thickly built-up outskirts of the town, and after that approximately the same distance over woodlands. The forest formed a dense wall to hinder the flying beetles in their search in a westerly direction. This experiment demonstrates that the pea weevil is able to fly a distance of three and a half versts.

The next experiment also illustrates this ability of the peas weevil to make long flights. In that same year we went from Belaya-Cerkov to Ustinovka (a distance of sixteen versts), planting small portions of disinfected pea seeds on small plots inside the peasant's plantings. These small plots were spaced at intervals of one verst. Thus there were in all fourtee n plots planted with peas, one at each verst of the journey from Belaya-Cerkov to Ustinovka. With one exception, a search of this locality convinced us of the total absence of any pea plantings in the vicinity. Nevertheless, when the pods on these plots were examined for eggs we found the weevil almost everywhere.

In 1927 all the ready supply of peas kept at the station, even to the individual packages in which they were collected, was subjected to a thorough treatment with fumes of carbon disulphide, Therefore all the planting of peas at the station was done with seed entirely free of the pea weevil. Nevertheless the weevils appeared everywhere, even in the most distant sections; apparently they had flown in from other warehouses in the city of Belaya-Cerkov.

Since it has not yet been proved that the pea weevil can exist in nature on any of the wild leguminous plants, and since in our climate this would evidently be impossible, the only way it could reach these distant fields is by flying there independently. How the insect is able to determine the location ofits host plant is a question that presents great interest.

From all this we are entitled to conclude that there are three routes by which the pea weevil, Bruchus pisi L., may attack peas. One route is by being brought onto the field in the seed that is planted, which occurs when the weevil that is inside the seed has not been killed. A second way by which it may appear on the field, as our experiment proves, is provided by the beetle's ability to seek out it a host plant independently. In infested regions this plays a very important part.

Lastly, those weevils that come out in the fall from seeds that have been dropped on the field, and winter under natural conditions, complete the list of circumstances under which we find the peas infested.

Dates of planting and resistance of pea varieties to infestation by the weevil, in connection with the working out of biological methods ~~ffr~~ for its control.

We had long noticed that there is ome connection between the liability of the pea to infestation and the time when it comes to fruit. Naturally the heaviest attack falls on the pea which comes to fruit at the period when the beetle is at the peak of its egg-laying activity. Observations on individual insects led us to conclude that this period is comparativeky short, and is wholly included within an interval of fifteen days, The pea weevil begins to do its damage in the first days of June, when it begins to infest the pea. At that time the earliest varieties are just coming into bloom. And since the weevil usually becomes sexually mature at this time, and the fruiting season of the pea is prolonged, these early peas are infested. The maximum infestation of peas takes place in the second and third ~~ten~~ days of June, which corresponds to the period when there are the greatest number of mature weevils in nature. After this the weevil becomes less active, since its numbers are dwindling. Only the late individuals are left in the open.

In our study of the biology of the pea weevil we considered the earliest dates for egg-laying as well as the causes governing the late infestation of peas. As we know, the weevil needs additional food when it leaves its cradle in the pea seed. The adult weevil does not eat the pea seed. It seems that the food required by the beetle must consist of juicy plant tissues which it seeks in the spring. We arranged a special experiment to study the length of the period of this supplementary food for the maturing of the eggs and the length of the starvation period.

Table 9. Length of starvation of pea weevil under various conditions

Month and date	Mar		April						May						June						July			
	26–25	26–31	1–5	6–10	11–15	16–20	21–25	26–30	1–5	6–10	11–15	16–20	21–25	26–31	1–5	6–10	11–15	16–20	21–25	26–30	1–5	6–10	11–15	16–20
1. Insectary																								
Beetles came out of seed	1			4	14	3	1	25	33	5	3	6	55	43	10	11				2	2	1		
Died of hunger																								
6/18	1			2	2			2		1	1	1	6	2	1									
6/28				2	2			9	4	2		1	24	5	7	6								
7/8					6	3	1	7	12		2		12	23	2	3								
7/19					3			6	9	1		4	9	8		2				2	2	1		
7/13					1			1	7	1			4	2										
7/28									1					3										
2. First floor storehouse																								
Beetles came out of seed					3	1	1	36	34	4	6	8	19	16	70	35	81	8	1	2	1			1
Died of hunger																								
6/28									1		1			1		3								
7/5									6					1	9	8								
7/8								2	12	2	1	6	7	4	26	11	1							
7/19					1			1	9	1	3	1	6	3	15	4	4			2	1			
7/23					2		1	1	6	1	1		2		13	5		5						
7/28								2				1	2	5	5	4	1		1					
8/14													2	2	2			3						

Table 9. Length of starvation of pea weevil under various conditions (Cont.)

3. Garret of storehouse																								
Beetles came out of seed	1	1	2		27	6	2	26	17	10	5	12	18	16	2	3	4							
Died 6/14			1		4			4	12	4			6	4	1									
6/17	1	1	1		13	5	2	15	3	4	1	9	8	8	1									
6/20					4	1		2	2		4	3	3	3		2	3							
6/29					6			5		2			1	1		1	1							

In order to determine the relation of the weevil to the peas that fruit earliest, pea plants were forced in pots in the hotbed in spring. When the warm days came on the plants were brought out into the open air, and at the same time some of the beetles which were just coming out of the seeds were given access to them.

The following table shows how the weevils reacted to peas which blossomed at the end of April and began their fruiting early in May.

Table 10.

Number in order	Date of planting	Date of shoots	Date of putting on isolators and letting in beetles	Number of beetles let in	Date of beginning to blossom	Date of appearance of pods	Date of beginning of egg-laying
1	3/18	3/23	3/27	20	5/10	5/16	6/5
2	"	"	"	"	5/4	5/9	6/1
3	"	"	"	"	4/30	5/5	-
4	"	"	"	"	"	5/4	6/4
5	"	"	"	"	5/5	5/9	6/4
6	"	"	"	"	5/6	5/12	6/1
7	"	"	"	"	5/4	5/9	-
8	"	"	"	"	"	5/9	6/1
9	"	"	"	"	5/1	5/4	6/4
10	"	"	"	"	5/2	5/7	6/1

Thus we see that the rhythm of development of the pea weevil in spring is more or less fixed. The weevil is not ready to attack peas that fruit in the month of May, and therefore we can easily admit that if there were a variety of pea that fruited so early

it would in all probability be beyond danger of infestation. Usually our earliest varieties begin to blossom only in the first part of June, in very rare instances at the end of May. This with the prolonged fruiting period of the pea exposes it to infestation. As a matter of fact it would scarcely be possible to create such early-ripening varieties of pea for spring planting. The only hope remaining is that we may somehow make use of winter varieties, thus beginning in the fall on the time necessary for germination, so that in spring the plants will begin to grow immediately and will come out earlier. Unfortunately the absence of winter pea varieties gave us no opportunity to test this experiment.

The use of late varieties has been recommended as one of the practical field measures to be taken against the weevil. Direct experiments on the length of the beetle's life allowed us to hope that peas which come to fruiting in July, for example, would be outside the danger period.

We took for observation and kept under natural conditions individual weevils which were of the same age, and they almost all died at the same time, after laying the necessary number of eggs. But with them were individual beetles which had left the pea seed later, and lived correspondingly longer. Unfortunately, in order to keep up an uninterrupted supply of weevils in the fields, we have beetles of different ages there. The result is that on the experiment plots even the peas which form their pods late, and ought by our reasoning to be free of weevils, are in fact infested. Sometimes these late plots are more heavily infested than the earlier ones. This must be ascribed to errors in the experiment. In their fruiting period the small plantings usually used for this kind of experiment present regular cases to entice any hungry weevil wandering anywhere around. At the same time, the weevils flying about have at this season become somewhat less numerous. Nevertheless, it does not seem possible to determine the liability of a pea to infestation by the date of its planting on these small plots.

For reasons of economic expediency a delay in planting the peas seems to be in many respects an undesirable method to use in coping with the weevil.

In view of this the objections to delaying the planting of peas seem quite sound. However, they may be modified in cases where peas of late varieties are chosen for the crop.

Table 11. Phenological observations on the pea in an experiment with dates of planting (variety Folger).

Plantings Dates	Date of planting	Date of shoots	50 shoots	Date of beginning to blossom	Date of 50 blossoms	Date of end of blossoming	Date of beginning to form pods	Date of beginning to ripen	Date of complete ripening
1st	4/9	4/25	4/16	6/9	6/14	7/7	6/14	7/12	7/23
2nd	4/16	4/28	4/30	6/12	6/15	7/9	6/16	7/13	7/23
3rd	4/22	5/14	5/6	6/13	6/16	7/10	6/18	7/16	7/26
4th	4/30	5/5	5/7	6/16	6/21	7/14	6/21	7/20	7/30
5th	5/7	5/16	5/18	6/22	6/27	7/17	6/26	7/25	8/4
6th	5/14	5/20	5/13	6/27	6/30	7/20	6/30	7/29	8/6
7th	8/21	5/27	5/28	7/1	7/4	7/28	7/5	7/2	8/9
8th	5/28	6/4	6/6	7/4	7/8	8/4	7/9	8/5	8/10

Table 12

ABSOLUTE WEIGHT OF 1000 SEEDS ACCORDING TO LAYERS OF PLANTS

Dates of Planting	1st layer	2nd layer	3rd layer	4th layer	5th layer	6th layer	7th layer	8th layer	9th layer	10th layer	11th layer	12th layer	13th layer	Average wt. of 1000 seeds
1st day- 9 April	178.3	174.4	163.6	165.7	158.7	158.1	150.4	146.7	144.0	136.2	131.6	112.4	98.8	147.6
2nd " 16 "	172.1	167.4	164.7	162.0	156.2	152.7	147.0	144.2	140.2	127.8	119.9	99.4	—	146.1
3rd " 22 "	170.7	166;5	158.1	156.6	150.7	146.4	141.9	138.9	135.1	120.5	121.4	92.6	—	141.6
4th " 30 "	166.5	160.0	155.3	144.4	137.1	132.7	130.5	123.1	116.0	103.5	104.4	—	—	134.0
5th " 7 May	162.4	153.9	140.6	136.3	134.0	127.2	124.1	107.0	108.1	104.7	—	—	—	129.8
6th " 14 "	139.8	133.4	118.3	115.8	113.2	115.7	115.4	110.4	91.8	65.6	—	—	—	111.9
7th " 21 "	126.7	118.4	106.4	100.5	95.0	90.1	78.2	61.5	56.1	—	—	—	—	92.5
8th " 28 "	110.1	94.9	93.2	84.6	74.7	58.4	49.0	—	—	—	—	—	—	80.7

Table 13

WEIGHT OF PEA SEEDS IN GRAMS ACCORDING TO LAYERS OF FRUITING

Dates of planting	No of plants studied	1st layer	2nd layer	3rd layer	4th layer	5th layer	6th layer	7th layer	8th layer	9th layer	10th layer	11th layer	12th layer	13th layer	Total yield of seeds in kilograms	Yield of straw in kilograms	Ratio of straw to grain
April 1st day-9	4180	583.8	681.8	733.8	569.7	474.0	353.9	228.2	101.6	39.1	12.6	3.7	1.5	0.7	3.78	5.15	1.36
2nd " 16	3496	768.9	825.7	732.7	584.4	382.0	246.9	127.8	50.8	20.5	9.9	3.4	0.7	---	3.76	5.06	1.35
3rd " 22	2873	669.2	765.2	680.1	559.9	375.6	221.2	105.9	50.6	22.6	8.4	2.7	0.6	---	3.46	4.52	1.32
4th " 30	1988	685.9	627.3	501.6	384.3	257.9	158.3	61.5	21.4	7.2	2.3	0.6	---	---	2.71	4.34	1.60
May 5th day-7	1963	504.3	468.2	369.1	267.9	166.7	82.4	31.2	8.6	2.1	0.8	---	---	---	1.90	3.96	2.08
6th " 14	1810	332.2	291.6	226.6	143.4	82.3	44.3	18.9	8.1	3.3	0.8	---	---	---	1.15	3.44	3.00
7th " 21	2056	231.2	191.6	130.1	77.4	39.3	17.1	4.7	1.9	0.5	---	---	---	---	0.69	3.04	4.41
8th " 28	2090	133.2	88.2	41.2	13.7	5.1	1.4	0.4	---	---	---	---	---	---	0.28	2.58	9.21

It is difficult to show in small experiments (plots of 14.5 square meters, six repetitions) a consistently diminishing liability of the pea to infestation in association with the date of planting. We have presented this in a table of the liability to infestation of peas planted at different dates according to the states or layers of the fruiting, see table 14).

Table 14. Infestation of peas by pea weevil by stages of fruiting in per cent

Plantings	1st stage	2nd stage	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	Average per cent of infestation	Total number of plants examined
First April 9	10.55	8.78	6.93	5.45	5.18	4.47	3.82	4.15	4.80	4.78	2.42	0.00	0.00	4.72	4180
Second April 18	8.10	6.23	6.08	6.80	5.20	4.62	4.13	5.09	2.92	5.32	2.32	0.00	--	4.73	3496
Third April 22	5.27	4.92	4.22	4.22	4.53	4.67	4.05	3.55	3.73	5.53	3.32	--	--	4.36	2873
Fourth April 30	4.23	3.88	4.87	4.93	5.52	6.15	5.75	6.10	3.75	5.43	7.50	--	--	5.24	1988
Fifth May 7	4.62	7.08	6.48	6.62	8.03	8.97	8.65	6.03	11.07	6.05	--	--	--	7.36	1963
Sixth May 14	7.08	7.60	8.40	10.35	9.93	11.20	10.43	9.43	11.52	7.35	--	--	--	9.33	1810
Seventh May 21	9.53	11.28	11.98	12.72	14.22	8.92	7.73	6.83	3.18	--	--	--	--	9.60	2056
Eighth May 28	13.32	14.52	15.08	17.93	12.70	8.07	0.00	--	--	--	--	--	--	11.66	2090

Peas from the upper layers of the first two plantings showed an infestation which amounted to zero. This means that there were so few weevils at large that they did not seize upon a single pea from the 7676 plants that were analyzed. From the middle of July, however, the peas begin to ripen on the fields of the ordinary farm plantation in the midst of which we had placed our experiment on dates of planting. This curcumstance causes a sharp jump upward in the liability to infestation of the peas of our experiment, beginning with the fourth date of planting. Peas of later plantings are attacked with increasing intensity in proportion as the insect among those flying at large finds an insufficient supply of material in the shape of young or still green pea pods. On a large farm planting of late fruiting peas there must necessarily be less damage.

As events showed, the plots with late plantings act as a decoy for the beetles still remaining on the fields, which concentrate here and give rise to the misleading deductions which are often made as to a greater liability to infestation of late varieties being tested on small plots. In actual fact this is not so, for it is not difficult to demonstrate by direct observations that in the month of July, i. e. at the end of life of the beetle stage, there are comparatively few of the weevils. We found a noticeable decline in percent of infestation of the pea by the weevil before the fourth date of planting. After this we see a sharp jump upward, coinciding with the period of ripening of the greater part of the pea plantings on the farm.

From this we must conclude that on large areas these data must be reversed.

Late peas will be least affected when a planting of some early variety of peas on a comparatively small area creates a kind of decoy for the greater part of the weevils on the field. Such reserves as remain after this step has been taken form a rather insignificient proportion for infesting the whole pea field. We have been advising that such a decoy be planted in the shape of a defensive band two or three plow-drills in width around the pea field. The difference in ripening dates between the decoy and the main crop prevents any danger of mixing the two and so adulterating the main variety. Of course these field measures are of value only where peas are planted on comparatively large areas, as is the case with our sovkhozes.

Hardiness of different varieties of pea.

There is no such thing, of course, as a pea variety that is absolutely resistant to the weevil. What we have to consider here is the relative resistance of the various kinds of pea. To be sure, the fluctuating figures our observations give on this point are not very reassuring, for the varieties change places from year to year.

At the Belaya-Cerkov selection station we have been planting for several years a collection of peas which by 1927 had reached a total of two hundred kinds. Nevertheless, in all these different varieties, we have not yet succeeded in finding, among those which are of any importance under farming conditions, any really hardy varieties which will suffer little infestation.

Moreover, the figures on the liability of the pea to infestation are likely to vary not only from year to year but even within the limits of a single year. Estimates made in the nursery of the liability of the pea varieties to weevil infestation are in most cases fortuitous in character, because they are governed by different conditions of density of weevils in those places and by the size of the experiment plots. The fact is that these experiments on the resistance to the weevil of different varities of pea are usually conducted on tiny plots, and the peculiarities of the separate varieties that appear here are likely to be ironed out if the experiment is often repeated. Nevertheless, in spite of the negative features of the task of estimating the resistance of separate pea varieties, differences do exist, though they can be discovered only in widely differing groups of peas. In the table given below are figures on the liability to infestation of several kinds of peas sorted into two groups standing at opposite poles as regards liability to infestation in our nursery. This series was made up of varities tested for liability to infestation and planted in 1926 in the nursery of the section on the selection of cereals and legumes.

The only one to show resistance to the pea weevil was an Afghan pea whose general native name is "Mushung". The other varities which were least attacked by the weevil in 1926 took the lowest rank in 1927.

Table 15. Comparative liability to infestation in two years of testing of peas of varieties most attacked and least attacked.

Name of Variety	Per cent infested by Bruchus pisi		Phenological observations in 1927			
	1928	1927	Date of planting	Date of shoots	Date of blossoming	Date of forming pods
Poischenile caterpil.	0.60	43.40	4/1	4/22	4/7	6/12
Sutton's original	0.00	41/67	"	4/24	5/28	6/3
Alaska	41.50	38.32	"	4/22	5/26	6/1
A 579	47.5	34.18	"	"	6/18	6/21
Tulun Hybrid	0.40	29.54	"	"	5/26	6/1
Variegated asparagus	1.10	26.28	"	"	6/12	6/16
P.gris de printemps	12.10	22.50	"	"	6/13	6/17
Maculatus 201	0.00	21.65	"	"	6/6	6/10
Delicates	0.50	20.00	"	4/24	6/12	6/16
Maculatus 196	0.60	10.40	"	4/22	6/7	6/12
Green Victoria	38.60	9.99	"	"	6/10	6/14
Mushung	0.0	8.70	"	4/26	6/6	6/10

As we had at our disposal peas belonging to different botanical groups, we attempted to study their liability to infestation according to their classification; results are given in the table below.

Table 16.

	Number of varieties	Average infestation in per cent M	m	Positive difference	Range of variation in per cent
1. Pisum sativum Gloucospermum	64	11.87	1.03	-	40.9
Vulgare	139	11.85	0.67	0.02	37.3
Vitelinum	14	10.39	1.27	0.91	16.6
Coronatum	12	9.15	1.28	1.66	14.7
Humile	27	7.77	1.03	2.82	20.7
2. Pisum arvense Unicolor	4	7.80	3.12	-	15.5
Maculatus	11	4/65	2.37	0.80	27.2
Punctatum	18	4.04	0.71	1.18	10.6

In spite of the apparent simplicity of this group arrangement of peas, it is difficult to come to any definite conclusions. Even more hopeless is the problem of grouping the liability of the peas to infestation by any other external characters. The size of the seeds does play some part, but a very small one. For the present it is believed that the small-seeded peas are less subject to attack. It is probably more likely that physiological features of the pea will give a more promising basis for judging of the causes of varying degrees of infestation.

When it has the choice, the pea weevil plainly prefer to lay its eggs on *Pisum sativum* rather than on *Pisum arvense*. It passes by several varieties in the latter group This is especially noticeable at the time when the eggs are laid; on some plots of peas (*Pisum arvense*) the eggs can be found only with difficulty, while neighboring plots of the common pea are litterally covered with the eggs. Moreover, some kinds of peas were visited by weevils very rarely. Thus we cannot doubt that the weevil has some method of discriminating between these two varieties of pea.

How the weevil is able to choose between different pea forms it is hard to say, but nevertheless the ability is there, and can easily be observed when the insect has a wide choice of food plants. We found that one of the peas least visited by the weevil was a field pea of the botanical group Maculatus, the so-called "Mushung", introduced from Afghanistan. This pea belongs to the group *Pisum arvense*, whose members are in general less subject to attack than *Pisum sativum*. Among other characteristics of this pea we should note the fact that the plant is low growing, with small pods and fine seeds. The parenchyma of the pod sometimes puts out little green wart-like projections which often cover the green envelope of the pod. These local thickenings of the tissue sometimes break out after the eggs have been laid, and thus cause the eggs to be displaced on the surface of the fruit so that in time they roll off.

From an agricultural standpoint, however, this pea is not of interest. Hence we are forced to the unwelcome conclusion that man's tastes and the weevil's agree, since the best varieties of this crop are the ones most eagerly attacked.

The parchment layer of the pea pod, and its rôle in the weevil's attacks.

The weevil's greatest obstacle in its attack on the pea is the so-called parchment layer of the pod, which consists of a series of layers of very firm thick-walled stony cells of parenchyma. With this mechanical barrier brought to a certain degree of hardness and thickness, the young larva should be faced by insurmountable obstacles to his penetration into the cavity of the pod. That is to say, this layer of cells which lines the inner cavity of the pod may be so thick that the larva newly emerged from the egg will not be able to cross it.

Usually, the larva does manage to cross it and get inside the pod by eating through all its wrappings. As an argument in favor of the possibility of preventing this, we may cite the comparable fact of the mechanical resistance to the caterpillar, Homoeosoma nebulella Hb. of the oil varieties of the so-called armored sunflower (D. M. Korolkov, "The Sunflower Moth", Proc. 4th All Russian Entomological & Phytopathological Congress, 1924).

The armored layer in the sides of the sunflower does not yield to the jaws of the caterpillar and so renders the sunflower almost invulnerable to the sunflower moth. This has made possible the control of a pest which had previously ravaged the sunflower in regions where it was intensively cultivated and, according to a study of similar anatomical features of the pea, constitute a very important step toward the solution of the problem of its resistance to the weevil.

We have long been interested in the question of the role of the so-called parchment layer in the possible mechanical resistance of the pea to infestation by its weevil, and only the lack of the equipment required for making accurate measurements of the thickness of the stony cells of the parenchyma has compelled us to attack the problem from another angle. Instead of using microscope slides to determine for a series of varieties the thickness of these cells and of the socalled parchment layer which they form, we worked out in 1925 a method for measuring the degree to which the newly hatched larvae of the weevil enter the cavity of the pod. For this purpose the pea pods were provisionally sorted in five ages and for each plant under observation note was made of the number of eggs on the fruit. After this the pods were isolated on the plants by means of small parchment isolaters and were left to ripen. As soon as they ripened, the pods which had been accurately labeled, were picked and all the seeds in them were subjected to analysis.

Unfortunately, we found that neigher age nor variety had exercised any appreciable influence on the liability to infestation of the agricultural pea varieties chosen for observation. See Table 17 (Table 14, page 24).

TABLE 17

LIABILITY TO INFESTATION OF PEA VARIETIES INFESTED BY THE PEA WEEVIL IN DIFFERENT STAGES OF THE DEVELOPMENT OF THE PEA POD.

Name of variety	Maturity of green pods in balls	Per cent of penetration of larvae into pea seeds	Per cent of beetles developing	Remarks
Rostov..........	5	68.5	57.5	
	4	86.9	82.7	
	3	46.7	38.9	Peas
	2	63.7	66.7	
Bismarck.......	5	93.1	60.9	without
	4	68.4	52.7	
	3	57.6	39.6	parchment
	2	89.4	62.2	
	1	50.0	100.0	layer
Alaska........	5	73.1	53.9	
	4	61.5	43.6	
	3	56.6	53.8	
	2	80.0	44.4	
Folger VUOS...	5	50.1	61.7	
	4	77.8	68.6	
	3	79.9	68.9	
	1	0.0	0.0	
Victoria Diozeger	5	67.5	54.8	
	4	63.2	46.8	
	3	59.6	45.0	
	2	72.5	75.0	Peas
	1	0.0	0.0	
Victoria Mandorf	5	63.6	63.6	with
	4	22.2	71.4	
	3	44.4	63.1	parchment
	2	80.0	100.0	
Folger Heine...	5	63.4	47.0	layer
	4	58.5	54.3	
	3	44.4	73.5	
	2	69.7	52.4	
	1	74.9	50.0	
Saxon..........	5	61.8	54.8	
	4	56.8	39.8	
	3	71.8	53.4	
	2	56.7	44.8	
Wonder of America	5	61.1	52.4	
	4	66.8	59.3	
	3	65.4	56.6	
	2	100.0	100.0	

(Table 14, p. ~~109~~ 24)

We must not overlook the fact that the pods of those varieties which are considered to lack a parchment layer (as a matter of fact, they have a correspondingly thickened layer of woody cells) were eaten into by the young weevil larvae to just the same degree as those which have a very well developed parchment layer, hence the greater damage done to the sweet varieties of peas is due not to the absence of parchment layer but to the weevil's preference for those peas. We repeated this experiment, this time noting the number of eggs laid by the weevil but only on the full-grown pea pods. Among a number of varieties which varied very greatly in their relations with the weevil we could scarcely distinguish any difference in the degree to which the larvae penetrated the cavity of the pod. A relatively smaller number of larvae, as may be seen from Table 15 below (Table 16, page 26), pierced the coverings of the pods of an Afghan pea, which goes by the general name "Mushung". This pea, as we have already mentioned, had in other respects little attraction for the weevil, as its pods were rarely visited. If we confine ourselves to the varieties here considered, the degree to which the weevil larvae pierce the parchment layer is too great to allow us to base any practical conclusions on the role of the parchment layer. To be sure these experiments are far from exhausting all the possibilities in this line. Among the many varieties of peas which exist there may be some in which this parchment layer possesses the necessary thickness and hardness, but we have not been able to discover them in the course of investigations which covered a great number of varieties.

The important factor seems to be not so much the thickness of the parchment as its hardness, governed by the extent to which the cell walls forming the palisade parenchyma have become woody.

So far, our observations do not enable us to draw any conclusions as to the existence of a connection between the liability of the pea to infestation and the character of the parchment as seen under the microscope. We shall find much to look at along the path indicated by our observations at the beginning of our work with the coverings of pea pods. By measuring the degree to which the larva is able to penetrate the cavity of the fruit in different varieties of pea, we shall be in a better position to judge what barriers may be raised against the young larva.

RELATION OF THE PEA WEEVIL TO OTHER GRAIN LEGUMINOUS PLANTS

It is generally accepted that the pea weevil is strongly specific to plants of Pisum sp.; in fact, it is probable that no one has succeeded in finding this weevil in the seeds of other leguminous plants. This by no means excludes the possibility that pea weevils may develop in the seeds of alien plants, as we were convinced by a small experiment. We put isolaters of light paper tissue on Cicer arietinum, horse bean, ground nut, lentil, and hog pea, and introduced weevils which we had caught in the open at the mement when they were attacking peas. We introduced also weevils which had just come out of seeds in the laboratory. The weevils confronted with these alien plants persistently refused to lay eggs on the green pods with the exception of the ground nut, on which 38 eggs were laid.

They prefer to establish their numerous eggs on the tissue of the inner walls of the isolater.

The weevil larvae which came out of the eggs on the green coverings of the pods of ground nut wandered around a long time on the outside layer. Their long winding tracks could be clearly seen on the pod tissue and made it very evident that the larvae were unwilling to penetrate the seeds. From the thirty-eight weevil eggs which had been laid on the ground nut pods, not a single larva went inside. They all preferred to die in close proximity to the great supply of food which the seed offered. Even so, the growth of a pea weevil in seeds of ground nut is not impossible, as we were convinced by an experiment of which I shall speak later.

After the pea weevils had clearly manifested their unwillingness to attack the ground nut, lentil, bean, and other leguminous plants we had chosen for this experiment, we arranged an artificial infestation of the plants. We did this by putting onto the plants being tested weevil eggs which had been laid on pea plants. Tables 17 and 18 show results of this experiment.

Blind instinct was too strong for the insect itself, for the weevil, as the figures show, developed well, even in the seeds of Cicer arietinum.

TABLE 16

LIABILITY TO INFESTATION AND THICKNESS OF PARCHMENT LAYER OF PODS IN VARIETIES MOST HEAVILY INFESTED BY PEA WEEVILS.

Name of Variety	Botanical group	Thickness of parchment layer in microns	Per cent of penetration of larvae into cavity of pod	Per cent of beetles developed		Liability to infestation by per cent
				From total: number of : eggs laid :	From no. of larvae which penetrated	
1 Poischenile caterpill.	glaucosperm	98	88.4	75.8	85.7	43.40
2 Sutton's Defender	gumile	99	86.7	64.8	69.2	41.67
3 Alaska	glaucosperm	106	76.8	61.1	79.5	38.32
4 A. 579	vitelinum	99	80.0	68.2	85.2	34.18
5 Tulun hybrid	vulgare	115	77.7	54.1	71.2	29.54
6 Asparagus varicolored	punctatum	88	81.1	59.0	72.7	26.28
7 P. gris de printemps	unicola	103	81.9	75.2	91.9	22.50
8 No. 201*	maculatus	78	80.2	63.5	79.2	21.65
9 Delicacy	punctatum	110	85.0	64.0	75.3	20.00
10 No. 196*	maculatus	77	62.7	43.1	68.8	10.80
11 Green Victoria	glaucosperm	81	84.3	68.5	81.5	9.99
12 Mushung	maculatus	68	71.9	58.8	82.0	8.70

*Names marked with an asterisk are taken from the catalogue of the Station's collections of peas. They were brought from Afghanistan by Prof. Vavilov's expedition; No. 201 from Khezar; No. 196 from Herat, and Mushung from Sebsevar.

TABLE 17

	Name of Plants	Date of planting	Date of blossoming	Isolation of beetles	Date of egg laying	No.of eggs laid	Number developed Of Larvae	Of Beetles
1	Ervum lens L.	12/IV	6/VI	14/VI	---	---	---	---
2	Vicia faba L.	22/IV	14/VI	"	---	---	---	---
3	Vicia sativa L.	"	16/VI	"	---	---	---	---
4	Cicer arietinum	12/IV	5/VI	"	---	---	---	---
5	Latyrus sativus	"	4/VI	"	18/VI	38	---	---

(p. 111)

TABLE 18

DEVELOPMENT OF PEA WEEVIL IN SEEDS OF DIFFERENT LEGUMINOUS PLANTS, ARTIFICIALLY INFESTED.

Name of Plant	No. of pods	No. of eggs put on	No. of seeds	Larvae Found 1st stage	2nd stage	3rd stage	4th stage	5th stage	Beetles found developed
1 Ervum lens L. , . .	20	20	29	--	2	3	--	--	7
2 Cicer aristinum . . .	10	10	14	--	--	--	--	--	7
3 Vicia faba L. . . .	5	20	22	--	6	2	--	--	2
4 Vicia sativa L. . .	5	20	23	--	2	4	--	--	--
5 Latyrus sativus . .	10	20	19	--	--	--	--	--	1
6 Latyrus odorata . .	5	20	22	--	--	--	--	--	--

TABLE 19

BEETLES OBSERVED TO COME TO THE SURFACE

Depth at which seeds were placed	No. of seeds planted	Date of planting	August 24	26	28	31	September 2	5	7	9	12	14	16	18	20	22	24	29	Total Emerged Absolute number	Total Emerged Per cent
Larval stage at surface of ground	240	5/VIII	1	3	5	10	3						1						23	9.6
4 c/m	"	"				1							1						2	0.8
8 c/m	"	"																		0.0
Pupa stage at surface of ground	240	19/VIII	4	5	11	17	4	6	5									6	48	20.0
4 c/m	"	"				1													1	0.4
8 c/m	"	"																		0.0
Imago stage at surface of ground	240	2/IX						166	8	10	11	5	2	3	4	5		2	216	90.0
4 c/m	"	"						98	13	24	19	5		1	11	5	2		178	74.2
8 c/m	"	"						19	6	5	5	4	5	2	6	2	3	1	58	24.2

TABLE 20

FUMIGATION OF PEAS IN DISINFECTION CHAMBER

No.	Capacity of chambers in cubic meters	Pounds of peas put in chamber	Quantity of carbon di-sulphide used in fumigation	Period of fumigation in hours	Tempera-ture C.	Results of Experiment: Beetles killed in percent	Beetles left alive
1	0.63	500	0.25 kil.	24	15°	100	--
2	"	"	0.15	24	13	100	--
3	"	"	0.2	8	23	100	--
4	"	"	"	24	21	100	--
5	"	"	0.1	16	22	94	6

This artificial infestation gave us fully viable beetles of Bruchus pisa L. from seeds of Cicer arietinum, lentil, beans, and ground nut. Probably some accidental factor reduced the number of beetles from the ground nut. In natural conditions here this plant is rarely attacked by Bruchus rufimanus Bohm.

The beetles that developed in lentil seeds were clearly undeveloped, only 3.2 millimeters long, and on October 12 we still found weevil larvae here, which shows the retarded rate at which they grew.

Results of this experiment indicate that the pea weevil's selective power with regard to its host plant, the pea, is only a matter of firmly engrained instinct, not always to its advantage.

COMPARATIVE DENSITY OF THE PEA WEEVIL IN DIFFERENT PARTS OF THE PEA FIELD.

The question of a decrease in number of weevils from the periphery of the field toward the center was of interest to us in connection with the general belief that many agricultural pests show this tendency. On the supposition that this is true of the pea weevil, we took appropriate field observations in 1927. Since this matter is of practical signifiance only on large areas, we made this comparative estimate of pea weevil infestation on sugar fields around us. On the sugar plantations the peas are planted over areas of several tens of desiatins, which greatly facilitated the taking of these observations.

In order to fix the per cent of pea infestation moving from the periphery toward the center, we took sample sheaves in the field every five meters, beginning at the periphery on all four sides and gradually converging toward the center of the field. Peas threshed from these sheaves were subjected to analysis in the laboratory for their weevil infestation. The fields of the Uzin, Ezerian, Shamraev combines were studied in this way. The diagram here reproduced is based on the results we obtained and shows clearly that there is a steady decrease in pea infestation from the periphery of a field toward its center. This is especially true of places abounding in weevils where the pea infestation fell to almost a quarter. On fields only lightly infested with the pea weevil, as , for example, on those of the Shamraev combine, we did not find this correlation. The average weevil infestation

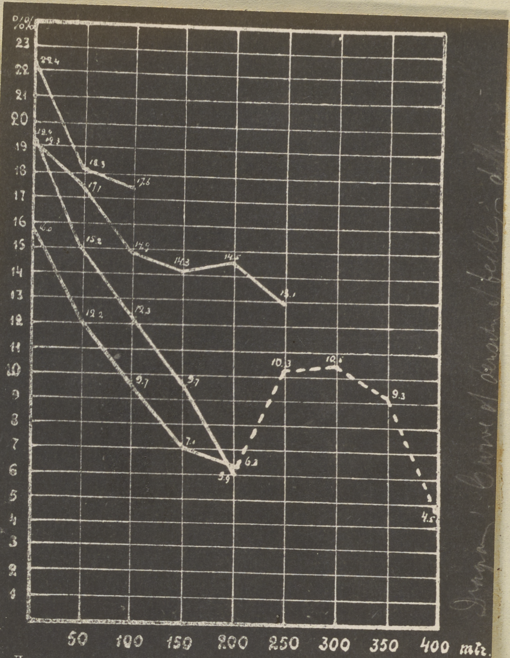


Диаграмма 1. Кривая плотности зерновки в различных частях поля.

Diagram 1. Curve of Density of Beetles in Different Parts of the Field

of the fields of this combine is only two per cent. Figures for the fields of the Uzin and Ezerian combines were quite different. There the relative weevil infestation of the peas in different parts of the field is of real practical significance. This indicates that with even one skillful operation the infested grain can be graded. In any case it is perfectly feasible to separate the grain from the outside strip of the field, which is most heavily infested, from the least infested grain in the central part of the field.

In each individual case the desired gradations must be fixed before the harvest by the very simple methods I have just mentioned. On small areas of a few desiatins, however, this method is not applicable.

THE ROLE OF THE FALLEN PEAS IN THE PRESERVATION OF THE WEEVIL IN NATURE.

After the peas have been harvested in the fields there remain a certain number which have been dropped. The weevils enclosed in these fallen seeds are doomed to live their whole lives in the open, exposed to all the hazards of the cold season.

For study of the behavior of the weevils left in the field in the fall we arranged a small experiment which will be briefly described.

In order to test the relations between the different stages of the pest living in the seed and the conditions under which the fallen peas lay on the field, we put 200 infested peas which contained all stages from larva to imago on an isolated tract under different conditions.

Part of them were left on the surface of the ground; part were put at depths of four and eight centimeters. The object of putting them on the ground was to estimate the effect of timely cultivation of the ground after the harvest. Results of this experiment can be seen at a glance in the table below, which shows how the pest behaved under various conditions.

Of those which remained on the surface of the ground until cold weather, 90 per cent emerged. From the seeds which contained beetles when they were put in the ground at four centimeters, 74.3 per cent of the insects crawled out; at eight centimeters, 24.3 per cent of the beetles.

The next younger stage of the weevil, the pupa, gave corresponding figures of 20 per cent emergence at the surface, 0.4 per cent at 4 centimeters, and zero at 8 centimeters. The larval stage of the weevil gave these results: At the surface of the ground, 9.6 per cent; at a depth of four centimeters, 0.4 per cent, and at 8 centimeters, zero. Of those from the seeds which already had beetles inside them at the moment when the experiment was begun there was the greatest rate of emergence. For the sooner the weevils can be caught by this working over of the soil, the fewer of them will survive and the more finely the soil can be plowed, thus promoting one of the measures to be taken for control of the weevil. While the destruction of the stubble weevils directly after the harvest can be accomplished by the usual husking (?), this is not enough to exterminate it later when it has come to the beetle stage, for the beetle crawls to the surface from a depth of eight centimeters.

RADICAL METHODS FOR CONTROL OF THE PEA WEEVIL

Our pea weevil is not a typical warehouse pest. In most cases it only completes its development in the warehouse after being brought in from the fields inside the seeds. The storehouse serves only as a temporary shelter where the weevil may spend its long period of winter, quite usually in the form of an adult beetle, inside the seed. Therefore, by killing it while it is in this helpless state, we do much to remove the danger that it will crawl out in the spring and infest the pea crop again.

There are a number of methods for control of the pea weevil. Unfortunately, no one of them has been widely applied, in spite of the fact that some of the measures if they could be simultaneously and universally applied on the farm would go a long way toward cutting down the numbers of this pest.

As matters stand now, the measures directed toward weevil control may be divided into three classes; 1, poisoning the

weevil enclosed in the pea seeds; 2, mechanically separating the weevil-infested seeds from the sound; and, 3, biological measures in the broad sense of the word.

One radical weapon against the weevil still enclosed in the pea seed consists of treating the seeds with fumes of carbon disulphide. Thanks to its relative simplicity, this method of killing the weevil is most feasible for fumigating large quantities of seeds. When the disinfecting is correctly done, this method is not expensive. It requires from 0.1 to 0.25 kilograms of carbon disulphide for each 500 kilograms of grain. Of course, this amount of carbon disulphide is used only when all the fumigating is done in containers especially made for the purpose, the so-called "hermetic-chambers" intended for this kind of fumigation. In case the whole granary is to be fumigated, the quantity of carbon disulphide to be used is figured on the basis of the cubic contents of the rooms. For each cubic meter of space there must be no less than 0.3 kilograms of carbon disulphide, which means three pounds to a cubic sazhene. (Sazhene equals seven feet).

This method, as is well known, does not impair the quality of the seeds, their viability or the flavor of foods made from them, provided, of course, the grain has come into contact with the fumes only. The carbon disulphide should never be poured on the grain, becuase it leaves a bad smell behind. The carbon disulphide does its most deadly work on the pest inside the seed in the course of the first six or eight hours. Nevertheless, the grain ought to be exposed to the poisonous fumes from 24 to 48 hours. This time may be shortened to twelve hours, depending on the dosage used and the temperature of the air, but the dose of carbon disulphide must under no circumstances be reduced. Best results are obtained by fumigating with carbon disulphide when the temperature of the air is above 12° C.

Carbon disulphide continues to be of great economic importance to us, as it is the most available insecticide for use in granaries.

Carbon disulphide has lost its world importance because of certain negative qualities. Nevertheless, it is now the most available insecticide for us and therefore we will now

stop to consider it in connection with the disinfection of the pea for Bruchus pisi L. In handling this insecticide it is of the utmost importance to understand its properties, which I think should be recapitulated here. Carbon disulphide is a heavy, strongly refractive liquid, almost colorless in clear water, with a specific weight at 15 degrees C. of 1.2, and with a very characteristic, unpleasant, radish-like odor. At ordinary temperatures it evaporates quickly. The great defect of carbon disulphide is the high inflammability of its fumes in the presence of any fire whatever. Carbon disulphide gas may produce a terrific explosion from a chance spark. Therefore, whatever is to done with it must be done in the total absence of fire. Carbon disulphide comes from the factory in iron casks. Before it is to be used, it is siphoned out into containers holding the desired quantity. It must be kept in a cool place in well stoppered vessels, and, furthermore, a little water must be poured on top to avoid loss by evaporation during the stirring. The water covers the surface of the carbon disulphide with an impermeable layer and prevents it from evaporating. This must be kept in mind when the disinfecting is to be done and the water poured off. The fact that the fumes of carbon disulphide are very poisonous and are heavier than air so that they settle makes this a very good fumigant for grain. It can permeate a very thick layer of grain. We found that in six or eight hours the carbon disulphide fumes in the chamber had permeated a layer of peas over a meter thick. Its action on the adult stage of the insect is very rapid, but it sometimes takes up to two days to force all the air from a thick layer of grain. For every thousand kilograms of peas to be treated in a tightly closed chamber, half a kilogram of carbon disulphide must be used, poured into a shallow earthen dish, and set above the grain. The treatment may be given to the peas in any large casks to be found on the farm, in iron vats like the one in the illustration, in tightly built boxes, etc. The tight covering, which is so important for the success of the disinfection, is done with canvas folded in several layers and well sprinkled with water.

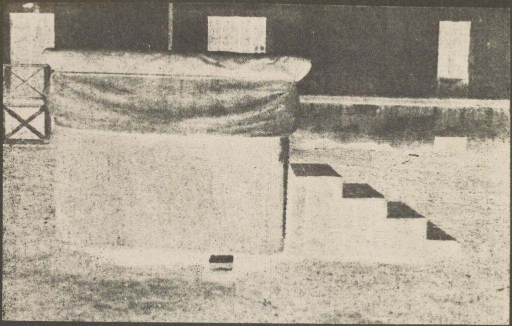
Such a covering gives little opportunity for the carbon disulphide fumes to escape, for water is a very poor conductor for this gas.

Of course, the disinfection of the grain can be best done in well built boxes with closely fitted covers. The covers may be put on with special screws. A box 2 meters long, one meter wide, and one meter high can be used to disinfect one thousand kilograms of grain at once. Half a kilogram of carbon disulphide will be needed and the process should be continued for 24 hours.

In place of carbon disulphide, the peas may be disinfected by the use of another very poisonous gas, hydrocyanic acid. This latter has been widely used in America for disinfection of farm products. For this, the product to be disinfected is put into a hermetically sealed container. The cyanic gas is formed by breaking down potassium cyanide with sulphuric acid. After the grain has been put in the chamber, one usually proceeds to prepare the acid, which is about twice diluted with water. The acid must be poured into the water, not the water into the acid or there will be violent reaction and splashing. The sulphuric acid must be quite pure. When this has been done, the dish of acid is placed in the chamber, a piece of potassium cyanide rolled in a filter paper is quickly dropped in, and the door instantly closed. To disinfect a ton of grain, the required quantity is 0.2 kilograms of pure sulphuric acid, specific weight 1.8 or 66 degrees by Baume's areometer and 20 grams of pure potassium cyanide. The high toxicity and pervasiveness of cyanic acid hastens the process of disinfection. Seed may be disinfected in two or three hours.

Among the defects of cyanic gas must be noted the fact that it is hygroscopic and is absorbed by the walls of the room; hence, all the work must be done not in rooms but in tightly closed dry chambers.

Cyanic acid is very poisonous and if it is present in the air, even in the ratio of 1 to 5,000, it paralyzes man in five minutes. Therefore, all work with it must be carried out with the utmost caution. Among the various poisonous substances which have recently been studied in connection with the control of warehouse pests is chloropicrin. This preparation, according to some authors, is more poisonous than carbon disulphide and equal to cyanic acid. Chloropicrin, $C(NO_2)Cl_3$, is a light yellow liquid with a boiling point of 112 degrees and a specific weight of 1.692. It is non-inflammable, insoluble in water, and non-explosive, and evaporates easily in ordinary temperatures. Besides this, chloropicrin has astonishing power to penetrate the walls of the insect's trachea and kill it very quickly. According to Moore and Graham, who have studied the use of chloropicrin in fumigating warehouses, it proved to be 283 times as poisonous as carbon disulphide. This does not make it dangerous to man, provided it is carefully handled,



Протравливание гороха на Белоцерковской Селекстанции.
Чан вместимостью 200 пуд.

Disinfection of Peas at Belaya Zerkov
Selection Station

because it is extremely irritating to the mucous membranes of the eyes, nose and respiratory passages, even in minute quantities. It does not involve so much danger of poisoning as carbon disulphide and cyanic acid, which could be breathed in unnoticed poisonous quantities. In spite of this, a few grains of this substance to a cubic meter of space is enough to cause death. The fatal dose for insects is one-eighth of a pound per cubic sazhene of space. In cases where rooms are to be disinfected, the dose must be doubled; that is, one quarter of a pound per cubic sazhene.

In order to make sure that the chloropicrin, which is slow to evaporate, will evaporate completely, it must be poured into shallow vessels to a depth of no more than a centimeter. The time required for disinfection is from 24 to 48 hours. Its fumes are heavier than those of carbon disulphide and hence it will permeate a greater thickness of grain, which is an advantage in combating grain pests, and among its other advantages must be noted the fact that it does not do any harm at all to legumes. Leguminous seeds which have been fumigated by chloropicrin do not lose any of their power to germinate and shoot. Several authors have found the opposite to be true. The disinfection has had a stimulating effect on the germination and further development of the plants. The chloropicrin has a fatal action only on the green plants. Unfortunately, the very high cost of chloropicrin as compared with carbon disulphide makes it impossible to use it on a large-scale at present. In view of the fact that the slightest particle of chloropicrin causes the flow of tears and has a very irritating effect on the mucous membranes, all work with it must necessarily be done with the protection of an ordinary gas mask. Among recent advances which have been made in America with regard to the disinfection of seeds against warehouse pests, mention should be made of the mixture of carbon tetrachloride with acetic ether. This is said to be an excellent method, but it is still a very expensive way to treat grain. Pure carbon tetrachloride is a colorless liquid of aromatic odor. While it is absolutely non-inflammable, it is at ~~the~~ same time half as poisonous agains as carbon disulphide, and as a result it is widely used over there.

Pushkarev has proposed a method for mechanically separating the clean peas not infested by the beetle from those which have been infested. This method is based on the dividing effect of certain solutions, especially nitre and

kitchen salt. With a certain concentration of this dividing solution, the seeds infested by the beetle will float because of the large cavity in them. Their specific weight is less than the sound grain, which sinks to the bottom. To illustrate this method of weevil control, I am including Pushkarev's empirical table for preparing a dividing solution for three types of peas -- those with large seeds, those with seeds of medium size, and those with small seeds.

In general, the concentration of solution in each separate case is fixed by the practical method of gradually adding salt to the solution until the infested peas put into the solution will float.

Table 21 follows:

TABLE 21

Variety of pea	Name of Salt	Specified wt. of solution	Concentration of solution in per cent	Amt. of salt required in lbs. for 1 vedro* of water	Amt. of salt in kilograms for 12.2 litres of water
Victoria	Chili saltpeter	1.296	40	20	8.80
Folger	" "	1.238	33.3	15	6.136
Rykhlik	Kitchen salt	1.192	25.0	10	4.09

*vedro equals 2.7 gallons.

A better dividing solution calls for some excess of salt, 0.82 kilograms to a vedro of water (12.29 litres). This addition raises the concentration by approximately 6 per cent.

One serious defect in this method of sorting the peas is a certain amount of delay, chiefly in connection with further drying of peas treated in this way. This causes insuperable difficulties in large lots of grain, such as are handled on the great farms of our Sovkhozes.

On peasant farms the Pushkarev method of weevil control must still be regarded as one of the best.

The use of high temperatures against weevils in the pea seeds is a very old method. A temperature of 45 to 55 degrees Reamur can be depended on to kill all stages of this pest in two hours and it does not injure the grain. Besides this dry heat method, the heat may be applied by plunging the infested grain into boiling water for a period up to one minute, but while the seeds can withstand dry heat for a period of several hours without detriment, the boiling water may destroy their viability if they are kept there a very little more than one minute.

To try out the possibilities of frightening away the weevils, we made experiments in the field with a number of bad smelling substances. We used "ruscalin", carbolineum, naphthali, paradichlorobenzol and creolin. We mixed these substances with sand and threw them on selected plots in the pea field at the time of fruiting, which was also the time of infestation. We supposed that the strong odor which pervaded these plots must drive away whatever weevils were there, but when we came to inspect the pea seeds we did not find any difference between the numbers infested here and on crops which had not received the treatment. Even on the plots with carbolineum and creolin, which do not evaporate so rapidly and consequently give off an odor much longer than the other substances, we could not see any substantial difference in the number of seeds infested. This destroyed in large measure our faith in the possibility of denaturing pea crops by planting aromatic plants in among the peas. (Table 22 follows).

TABLE 22

Name of Substance	Area of experiment plot	No. of times experiment was repeated	No. of seeds analyzed	Infestation of peas in per cent
"Ruscalin"	100 K.M.	3	9000	5.96
Naphthali	"	4	12000	5.54
Carbolineum	"	4	"	5.31
Paradichlorobenzol	"	4	"	4.93
Creolin	"	3	9000	4.16
Control	---	---	"	6.96

Disinfection of peas infested by the pea weevil is of special importance in those cases where it is desired not only to kill the pests in the seeds but also even more to reduce the numbers for the coming year. When it is done immediately after the peas are harvested, and in this case they must be rapidly threshed and put in the storehouse, such disinfection increases the commercial value of the crop. At the time when the peas are being harvested in the field, the weevil is inside the seed in the shape of a young larva, so that if his destructive work is interrupted, it is impossible to tell from the outside how far the infestation has gone, but when the seeds are opened, they are found to have a small cavity of the same size as the larva which once lived there and which, after its death, dried up and became a small brown lump. Our observations of the result of prompt treatment of the pea seeds, for the purpose of arresting further destruction of the seed by the weevil larva, left us fully persuaded of the effectiveness of this method. However, it requires early harvesting of the peas, prompt threshing, and disinfection of the seeds immediately after threshing. How necessary promptness is to this method is made plain in the following tables, which show the development of the weevil inside the pea by varieties. This may serve as a guide to the best time for carrying out the disinfection.

(Insert Tables 23,24 and 25).

TABLE 23

LOSS IN WEIGHT OF WEEVIL-INFESTED SEEDS IN DIFFERENT VARIETIES OF PEA

Name of Variety	Absolute weight of 1000 seeds		Loss in weight by infestation	
	Uninfested seeds	Infested	In absolute weight	In Per Cent
Nyasa	363.8	328.7	35.1	9.6
Victoria Mandorf	332.3	295.2	37.1	11.2
" Heine	328.3	287.4	40.9	12.5
" Gerning	234.6	193.9	40.7	17.4
Folger VUOS	189.4	147.8	41.6	22.0
Saxon	187.7	140.0	47.7	25.4
Folger Heine . . .	177.7	141.1	35.6	20.0
Bismarck	150.4	104.9	45.5	30.3

TABLE 24

DEVELOPMENT OF BRUCHUS PISI IN PEA SEEDS
ACCORDING TO OBSERVATIONS MADE IN 1926.

No.in	Date of observation	Age of Larvae in Per Cent: 1st age	2nd age	3rd age	4th age	5th age	Pupae in Percent	Imago in Percent
1	3/VII	37	63					
2	5/VII	80	20					
3	8/VII		70	30				
4	10/VII	28	32	40				
5	12/VII	12	47	41				
6	13/VII	6	38	47	9			
7	15/VII	5	37	45	13			
8	17/VII		19	39	39	3		
9	19/VII	2	5	42	46	5		
10	21/VII			33	55	12		
11	23/VII		5	38	52	5		
12	24/VII		6	31	52	11		
13	28/VII			29	29	29	13	
14	30/VII			8	46	38	8	
15	2/VIII				9	64	27	
16	4/VIII				12	34	54	
17	7/VIII				8	28	61	3
18	10/VIII				8	21	67	4
19	28/VIII					2	74	24
20	3/IX						34	66
21	16/IX						13	87
22	24/IX						7	93
23	27/IX							100

TABLE 25

PER CENT OF STAGES OF WEEVIL IN DIFFERENT VARIETIES OF PEA

Date of observation	Victoria Heine			Folger Heine			Moscow Station		
	Larva	Pupa	Imago	Larva	Pupa	Imago	Larva	Pupa	Imago
27/VII	100.0								
29/VII	97.1	2.9							
30/VII	95.3	4.7							
1/VIII	77.4	22.6							
3/VIII	76.7	23.3		100.0					
5/VIII	60.0	40.0		97.1	2.9				
8/VIII	31.4	68.6		92.1	7.9				
10/VIII	32.4	67.6		76.3	23.7		100.0		
12/VIII	24.2	72.4	3.4	51.3	48.7		96.2	3.8	
14/VIII	14.3	77.1	8.6	35.3	64.7		91.2	8.8	
16/VIII	15.8	60.5	23.7	24.4	75.6		85.2	14.8	
18/VIII	9.2	45.4	45.4	21.9	75.0	3.1	78.8	21.2	
20/VIII	2.6	42.2	55.2	19.6	70.6	9.8	54.3	45.7	
22/VIII		38.4	61.6	10.0	72.5	17.5	50.0	50.0	
24/VIII		34.2	65.8	5.6	69.4	25.0	42.9	57.1	
26/VIII		27.5	72.5	2.8	51.2	46.0	21.9	75.0	3.1
28/VIII		9.7	90.3	2.5	37.2	60.0	14.7	64.7	20.6
30/VIII		7.9	92.1		29.7	70.3	3.2	58.1	38.7
1/IX		9.5	90.5		26.5	73.5	2.4	40.5	57.1
3/IX		6.7	93.3		11.8	88.2		34.5	65.5
5/IX		6.4	93.6		8.8	91.2		27.2	72.8
7/IX		6.1	93.9		5.7	94.3		21.6	78.4
9/IX			100.0		5.3	94.7		19.0	81.0
12/IX					2.7	97.3		9.5	90.5
14/IX					2.4	97.6		8.3	91.7
16/IX						100.0		4.2	95.8

Table 25 shows that the weevil larvae, which have gone through five moltings in the course of their development, usually begin to reach the adult stage about the 15th of August in some varieties; about the end of August in others, and sometimes, depending on the variety, the beetles may develop early in August.

The following table shows the specific weight of the pea which has been infested but has been disinfected in time as compared with the pea which already contains a full-grown beetle.

(Insert Table 26).

TABLE 26

ABSOLUTE WEIGHT OF 1000 SEEDS OF WEEVIL INFESTED PEAS WITH AND WITHOUT THE TREATMENT.

No. and Order	Name of variety	Absolute weight of 1000 seeds: Treated in larval stage	Not treated at all	Loss in Weight: In Grams	In per cent
1	Alaska	176.0	167.0	9.0	5.1
2	Folger heine	171.0	157.0	14.4	8.3
3	Victoria mandorf	319.0	309.8	8.2	2.5
4	Nyasa	351.2	331.6	19.6	5.5
5	Saxon	160.8	157.4	2.2	1.3

Thus it is clear that this method is a desirable one from many other standpoints. Besides preserving the quality of the grain, it is a measure of great importance from a purely sanitary point of view. The simultaneous exertions of many pea growers might well bring about a significant diminution in the numbers of this pest in any given locality. If it is open to objections, they can be only on the technical side of the problem of making such a disinfection as requires for its accomplishment a period of very intensive work just at harvest time, especially at the time of threshing the grain. Nevertheless, it ought to be generally recognized that by one method or another every pea grower ought to take some steps to destroy the weevil while it is still in the warehouse and inside the pea. At the present time seed materials are already being widely treated to prevent various fungous diseases. Treatment of peas must also be accepted as one of the obligatory defense measures in view of the fact that our whole supply of weevils is being cultivated on equal terms with the peas by the farmers themselves on their own farms. This melancholy fact is of general concern, for the pea weevil, <u>Bruchus pisi</u> L., lives only in the seeds of the pea. We have no definite information on the possibility of finding it on wild legumes in this country. Therefore, almost all our present supply of this pest must be kept all winter in the granaries; then, finding themselves in a trap easy to escape from, they crawl out in the spring unhindered by us to accomplish once more their destructive work.

While various methods of treating grain to prevent fungous diseases are making headway among us and are regarded as obligatory by many farmers, a comparable protection of the pea seeds against the pests inside them is provided almost nowhere. Yet this is, in my opinion, one of our chief responsibilities as regards this crop, and no other defensive methods have yet been adequately worked out.

An experiment in simultaneous attack on this weevil has also been undertaken in the United States of America in California around San Mateo. In the three years from 1918 to 1920 a systematic destruction of the weevil while the harvest was being gathered reduced the infestation of pea seeds from 43 per cent to 17.8 per cent.

We may well imitate this American feat. The work must be carried on systematically with greatest care until we succeed in mastering the weevil and keeping it within such bounds as we fix. Meanwhile, persistent work on the study of the natural defensive properties of the pea which may be used against the weevil may well supplement these efforts which are not yet in a position to afford adequate control of the pest.

Since 1926, that is, for two years, the Belaya-Cerkov Selection Station has been treating with carbon disulphide its entire stock of seeds. Thus, our plantings, beginning in 1926, have been made entirely with sound seeds. Already we seem to be able to trace the effect of this step on the pea infestation at the station in the past two years. Let us take, for purposes of comparison, the pea infestation for 1925, when the fumigation had not been begun. In that year the average per cent of grains infested was 21.5. In 1926 we began the treatments, and immediately the figure for pea infestation fell to 14.4 per cent, and for 1927 we have an average figure for pea infestation of about 7 per cent.

(Insert Table 27).

TABLE 27

WEEVIL INFESTATION OF PEAS PLANTED AT THE BELAYA CERKOV SELECTION STATION

1925 — Not Treated

No.	Name of Variety	Infestation in per cent M	m	$\frac{M_1 - M_2}{\sqrt{m_1^2 + m_2^2}}$	Groups by infestation
1	Folger VUOS	27.11	1.60		
2	Rostov	26.33	1.33	0.32	
3	Victoria VUOS	25.70	1.88	0.67	I
4	Victoria Heine	24.53	1.44	1.20	
5	Folger Heine	23.23	1.36	1.84	
6	Wonder of America	19.26	1.33	3.82	
7	Alaska	18.94	1.36	0.12	
8	Victoria Diozeg	17.24	1.37	1.01	II
9	Saxon	15.08	1.15	2.32	

1926 — Treatment by carbon disulphide introduced

No.	Name of variety	Infestation in per cent M	m	$\frac{M_1 - M_2}{\sqrt{m_1^2 + m_2^2}}$	Groups by infestation
1	Victoria Mandorf	32.30	1.48		I
2	Victoria Heine	28.70	1.43	1.75	
3	Alaska	15.80	1.15	8.80	II
4	Nyasa	10.90	0.98	3.23	
5	Bismarck	9.27	0.75	1.32	
6	Victoria Gerning	8.70	0.89	1.66	III
7	Folger Heine	8.30	0.87	1.98	
8	Folger VUOS	7.87	0.75	2.45	
9	Saxon	5.60	0.73	4.33	IV

1927 — Treated with Carbon disulphide

No.	Name of variety	Infestation in per cent M	m	$\frac{M_1 - M_2}{\sqrt{m_1^2 + m_2^2}}$	Groups by infestation
1	Victoria Mandorf	16.92	1.20		
2	Victoria Heine	15.75	1.15	0.70	I
3	Bismarck	12.22	1.04	2.97	
4	Alaska VUOS	12.07	1.03	3.07	
5	Early Green	10.87	0.98	0.84	
6	Rostov Sugar	8.95	0.90	2.28	II
7	Canadian (?)	8.92	0.90	2.30	
8	Green Saxon	8.82	0.90	2.38	
9	Nyasa	6.45	0.78	4.36	
10	Victoria	4.17	0.63	2.27	
11	Folger Heine	4.05	0.62	2.41	III
12	Victoria Gerning	3.75	0.60	2.75	

Under such conditions as we have at Belaya-Cerkov, where there are many traders in grain, there is no question of more or less complete extermination of the weevil. The weevils that we gather in every year in our pea harvest probably come from this market grain, having flown from there to our fields. The farms hear the station contribute comparatively few.

Farms, which are more or less remote from any stores of infested peas and which give a thorough treatment to all their stock of seed, might achieve more conspicuous results in the fall.

Difficulties arising in connection with the necessity for fumigating the pea seeds might be circumvented by keeping the whole stock of seeds from the last harvest in closely woven bags. Then the seeds from the preceding harvest are used for planting. The weevils will not be able to come out of the closely woven sacks in the spring and will be doomed to death. If some of the beetles remain alive, there will be only a few, and they will be so much weakened that there will be no question of long survival; but in view of the weevil's ability to fly idependently from the granary to the fields planted with peas, this procedure for isolating the infested grain must be carried out with the utmost care.

Either by this method or by some other device for protecting the young seeds from the weevil, persistent effort must be directed toward the end of destroying it in the pea seeds. This effort must be shared as widely as possible among the farmers concerned, and it should be kept well in mind that all the diligence of one group in endeavoring to exterminate the weevil may easily be paralyzed by the neglect and inactivity of others who are indifferent. For this reason, the control of the weevil in the pea seeds by one means or another should be regarded as morally obligatory upon all who are raising any of this crop.

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ILLUSTRATIONS.

Fig. 1 -- Pea Weevil, Bruchus pisi L. Original drawing by S. A. Smirnov.

Figs. 2 and 3 -- Larva of first phase and full-grown larva of pea weevil. (Original drawing by author).

Fig. 4 -- Eggs laid by pea weevil on pea pods.

Fig. 5 -- Weevil Eggs on pea pods (Original drawing by author).

Fig. 6 -- Varying size of seeds of peas injured by Bruchus pisi L.

Fig. on page 117 -- Disinfection of peas at Belaya-Cerkov Selection Station: capacity of vat, 200 pounds.